Scientists predict pulsar starquakes

June 5 2006

Scientists have discovered how to predict earthquake-like events in pulsars, the dense remains of exploded stars. These are violent episodes that likely crack a pulsar's dense crust and momentarily increase its spin rate.

John Middleditch of Los Alamos National Laboratory led the discovery team and presents these findings today at the American Astronomical Society Meeting in Calgary.

Middleditch and his team have discovered that for one particular pulsar, named PSR J0537-6910, the time until the next quake is proportional to the size of the last quake. Using this simple formula, the scientists have been able to aim NASA's Rossi X-ray Timing Explorer at the pulsar a few days before a quake to watch the event unfold.

Using the Rossi Explorer, the team has tracked about 20 "starquakes" in this pulsar over the past eight years and uncovered a remarkably simple, predictive pattern.

"By monitoring the pulsar spin rate and changes in the spin, we can pin down a starquake event to within a couple of days," said Middleditch. "These and other details have helped to simplify what has, until now, appeared to be a bewildering assemblage of facts about starquakes in pulsars. If only predicting earthquakes were this straightforward."

Once several times more massive than our sun, a pulsar contains about a sun's worth of mass compacted in a sphere only about 20 miles across. A pulsar is so dense that a teaspoon of its material would weigh two billion tons on Earth. The pulsar is so named because from our perspective it pulses with radiation from its two magnetic poles as it spins, sending two lighthouse-like beams through space.

PSR J0537-6910 is located in a 4,000-year old supernova remnant near the Milky Way galaxy, about 170,000 light years from Earth, visible in the Southern Hemisphere.

The pulsar is known for its frequent quakes, which scientists call glitches. Pulsars are born spinning rapidly, but gradually slow down. During a glitch, the spin rate increases slightly. PSR J0537-6910 spins at a rate of about 62 times per second, or 62 hertz. During a glitch, this pulsar's spin jumps up as much as one cycle every seven hours, a greater gain than what is seen in any other pulsar. Then the pulsar proceeds to slow down again.

After about 10 glitches since monitoring began in 1999, the scientists saw a pattern. The amount of increase in spin with each glitch could be translated directly into the number of days until the next glitch. Larger glitches meant a longer wait until the next one.

The predictive nature of these glitches firms up the leading theory on their cause. Pulsars have a solid crust, but are permeated with a liquid "neutron superfluid." Much of the crust's own superfluid does not slow with the pulsar, but when the difference in rotation rates exceeds a certain threshold, a large fraction of the excess can be "dumped" into the solid crust through massive cracking, making the pulsar spin faster.

The major glitch is always preceded by small ones, representing local dumps of rotation due to localized, small cracking. "A month ago we were watching the pulsar get the 'jitters' before the big quake," Middleditch said. "Then, by May 7, 2006 the big one had happened. We can only predict one glitch at a time."

Middleditch's colleagues include Frank Marshall and Will Zhang of NASA's Goddard Space Flight Center in Greenbelt, Md.; Eric Gotthelf of Columbia University in New York; and Daniel Wang of the University of Massachusetts, Amherst.

Middleditch noted that his team also found evidence the pulsar's magnetic pole is moving a few feet every year. Although a known feature on Earth, this is the first strong case for magnetic pole migration on a pulsar.

Source: Los Alamos National Laboratory